NOTES ON THE EFFICIENCY OF VARIOUS SYSTEMS OF AIR-CONDITIONING IN A MUNITION FACTORY.

By C.-E. A. Winslow, Professor of Public Health, Yale School of Medicine, Senior Sanitarian (R), United States Public Health Service; and Leonard Greenburg, Assistant Sanitary Engineer (R), United States Public Health Service.

1. INTRODUCTION.

It should be a truism that the success of any system of ventilation (or air-conditioning), natural or artificial, will depend on the intelligence with which the system is designed and the care with which it is operated. The literature of the subject is, however, notably deficient in detailed and critical study of the actual performance of such systems under the normal conditions of everyday use. The engineering journals carry elaborate accounts of the design of ventilating apparatus; but, once installed, we hear nothing more of them if they work well; whereas if they fail, the result is usually a sweeping condemnation of the whole practice of fan ventilation, without any serious attempt to discover the exact source of the difficulty.

Careful records of operating results are therefore likely to be of real value in furthering the development of the difficult and important art of air-conditioning. For this reason it seems worth while to present certain results obtained in the years 1918 and 1919 in a somewhat exhaustive study of the atmospheric conditions maintained in a small-arms plant in the State of Connecticut. The plant in question was unusually well adapted for a study of this sort. It included over 100 separate buildings, of which 24 old brick buildings 2,000 to 6,000 square feet in area, 22 larger and more modern concrete buildings, and 10 buildings of the mill construction type were surveyed in more or less detail. The greater number of the workrooms involved no special air-conditioning problems and furnished good examples of the ordinary factory workroom ventilated by windows only; but 13 of the workrooms studied were equipped with systems of fan ventilation, many of them of admirable design, while in several instances heat hazards of considerable magnitude were involved.

2. GENERAL SURVEY OF TEMPERATURE CONDITIONS IN THE PLANT.

First of all it seemed desirable to obtain an idea of the general temperature conditions maintained in the plant in the average workroom where no particularly complex problems of ventilation were involved. Studies along this line were therefore made in 100 different workrooms between February 17 and March 17, 1919. Five wet and dry bulb temperature readings were taken, at representative points in each shop, with the sling psychrometer. The distribution of the average dry-bulb temperatures and relative

humidities for each shop obtained from these readings is indicated in Table I below.

TABLE I.—*Winter temperature and relative humidity of workrooms.*

	Percentage of workrooms in each class.
Temperature classes (degrees F.):	
60–64	5
65–69	27
70–74	53
75–79	11
80–84	4
Relative humidity classes (per cent):	
Under 21	4
21–25	27
26–30	17
31–35	14
36–40	12
41–45	13
46–50	4
51–55	6
Over 55	3

These figures indicate comparatively little extreme overheating, only 4 rooms out of 100 studied showing an average temperature over 80°. These four rooms were a wash shop, a bluing shop, and two browning shops, in all of which there are special sources of heat, which make it very difficult to maintain a low temperature. On the other hand, there is evidence of a general tendency to slight overheating throughout the plant. A temperature of 68° is the highest which should be generally maintained in the factory workroom; but 68 per cent of the rooms studied showed a temperature of over 69°. When it is recalled that the investigations of the New York State Commission on Ventilation showed a decrease of 15 per cent in productivity when physical work was performed at 75° (as compared with 68°), it is evident that this condition of overheating is deserving of serious attention. It is typical of the most nearly universal problem of air-conditioning—a problem which does not require for its solution the installation of any elaborate system of fan ventilation, but involves merely the systematic observation of a thermometer placed in every workroom and the intelligent regulation of heating appliances.

3. DETAILED STUDY OF ATMOSPHERIC CONDITIONS IN A WINDOW-VENTILATED WORKROOM.

In order to see whether the high temperatures observed in the window-ventilated rooms were due to the inevitable accumulation of the heat produced by the bodies of the occupants or merely to initial overheating, we made a special study of the progressive changes taking place in a typical workroom. The room selected was a paper shell inspection shop provided with no artificial ventilation. It had a total capacity of 120,790 cubic feet and was occupied

by 53 female and 10 male employees, giving an ample allowance of 1,917 cubic feet per capita. The direct heating coils had been cut off at the time our observations began, and several windows were open at the bottom. The results of our examinations, which were made between 2 and 5 p. m. on a clear day in February, are shown in Table II, and in graphic form in Figure 1.

TABLE II.—*Ventilation observations in paper shot shell inspection shop. Feb. 24, 1919.*

Time.	Heat loss, millicalories per square centimeter per second.		Psychrometer.		Per cent relative humidity.	CO_2. Parts per 10,000 of air.	Remarks.
	Kata wet.	Kata dry.	Wet.	Dry.			
P. m.							
2	13	3.3	57.5	77.5	26+	....	Weather, clear.
2.15	14	3.6	54.5	76.0	21	7.8	
2.30	14	3.8	54.0	75.0	21	7.6	A few windows were open at bottom.
2.45	16	3.8	54.0	75.0	21	6.4	
3	16	3.8	53.0	73.5	20+	5.6	
3.15	15	3.8	53.0	73.0	22	8.3	Comfort vote: Slightly warm till near 5 p. m.
3.30	14	3.8	53.5	73.5	22	8.8	
3.45	15	3.9	54.5	74.0	25	7.4	
4	15	3.7	54.0	74.5	22	7.7	
4.15	15	3.8	55.0	76.0	22	8.7	
4.30	15	3.8	54.0	73.0	25	7.6	
4.45	15	4.0	53.0	73.0	22	8.9	
5	15	4.1	54.0	73.5	24+	6.7	

It is evident that the workroom was greatly overheated at the beginning of the work period, but that during the afternoon the natural ventilation taking place was not only sufficient to prevent a further rise but, with the gradual decrease of temperature outdoors, to produce a material lowering of the temperature of the workroom itself. The CO_2 rose slightly to between 8 and 9 parts per 10,000. It would seem in this instance that natural ventilation would have been quite adequate if means had been taken to cool the room off to 68° during the noon hour. In the absence of this precaution the temperature at 2 p. m. was 77.5° and stayed around 73° or higher for the whole afternoon. We have here an illustration of the fact that the use of a thermometer and a little common sense will solve a great many "ventilation problems."

4. DETAILED STUDY OF ATMOSPHERIC CONDITIONS IN AN ANNEALING SHOP WHERE AN INTENSIVE HEAT HAZARD WAS CONTROLLED BY FAN VENTILATION.

An interesting comparison may be drawn between the results obtained in the case described above and those observed in an annealing shop. The paper shell inspection shop could easily have been kept comfortable by a little attention to window ventilation; yet it was, as a matter of fact, notably overheated. The annealing shop, on the other hand, offers one of the most difficult problems of ventilation

in the plant under investigation; and yet this problem at the time of our observations was solved with remarkable success.

The annealing shop has a capacity of 119,160 cubic feet and contains a row of large rotary annealing furnaces on each side of the room. An annealing furnace consists of a cast-iron drum about 8 feet long, mounted horizontally in a casing, and arranged so as to revolve on large bearing wheels. A system of torches is arranged in

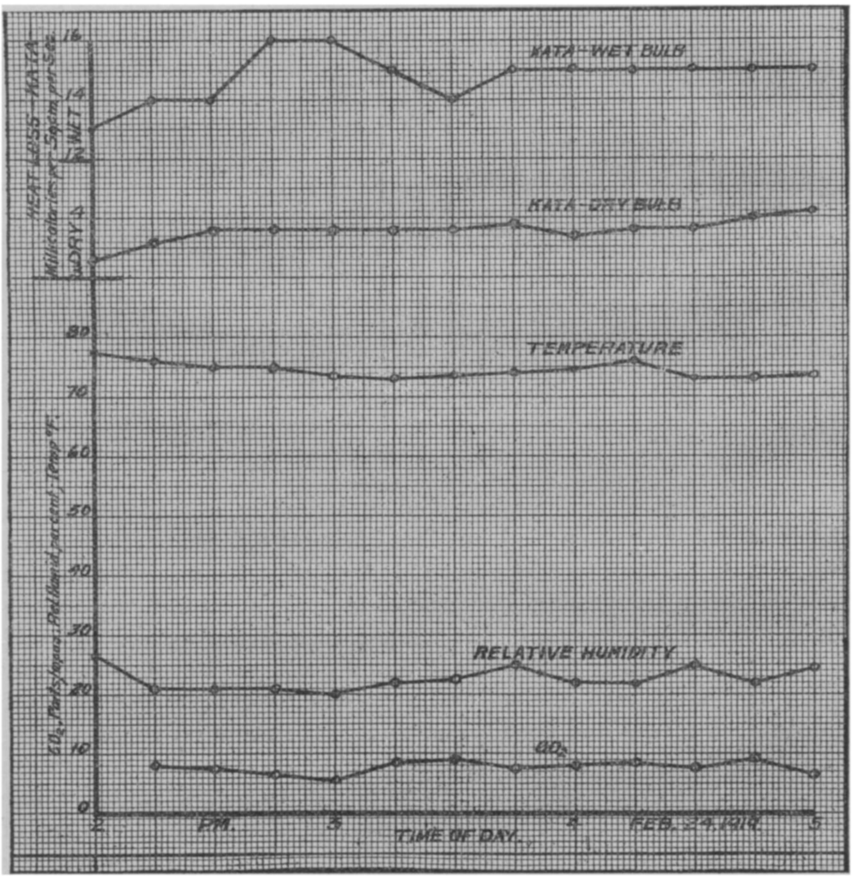

FIG. 1.—Progressive changes in atmospheric conditions in paper shot shell inspection shop. Window ventilation only.

the casing, and as the interior drum revolves, the torches (burning producer gas) heat the drum and the contained shells to the proper annealing temperature (generally about 1,200°). The shells are fed in at one end of the drum and, by means of a spiral ridge on the interior, work their way through the drum and fall out at the rear end.

The heating effect of these furnaces upon the room is naturally great, and in the summer time a very considerable heat hazard is

inevitable (see section 6 of this report). The room is, however, provided with an extensive system of fan ventilation which, when the weather is cold, is amply sufficient to keep conditions good. The system includes a plenum system delivering air to both sides of the room at the floor level and another plenum duct along the center of the ceiling. For the propulsion of the air two air washer fans are used, each having a capacity of 45,000 cubic feet per minute. The

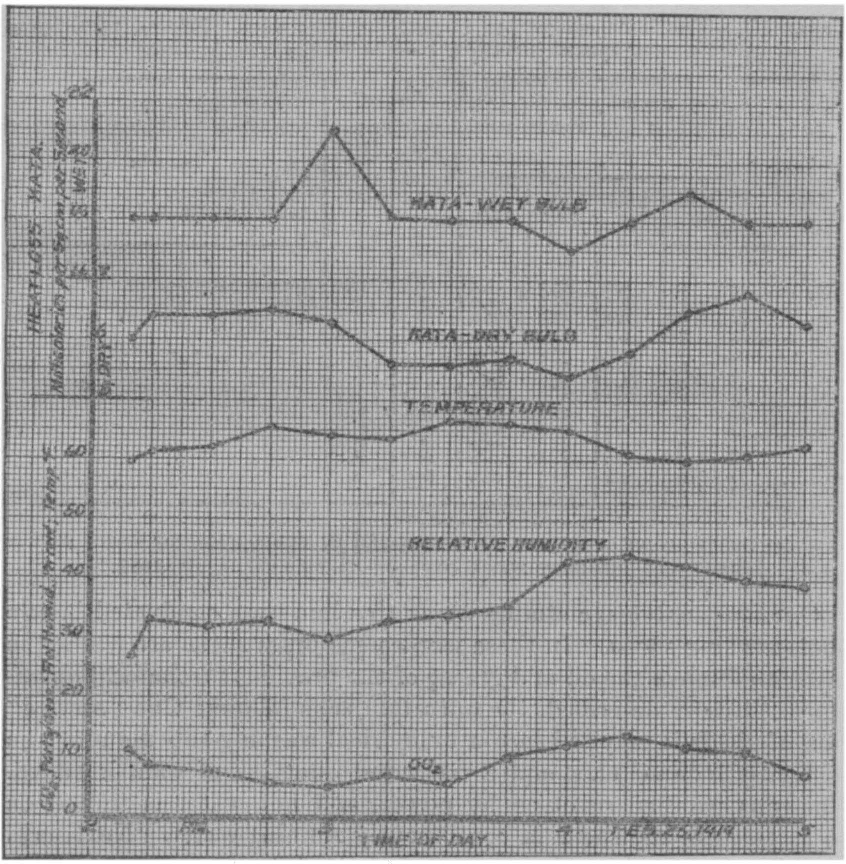

FIG. 2.—Progressive changes in atmospheric conditions in shell anneal shop. Heat hazard controlled by fan ventilation.

exhaust system consists of a series of hoods above the annealing furnaces along the sides of the room. For moving the air in this case, two fans are used; one being driven by a 25-horsepower and the other by a 20-horsepower motor.

We observed conditions in this room on a cool day in February, when the outside temperature was 44° F. on the dry bulb and 39° on the wet bulb. The results as indicated in Table III and Figure 2 showed that while the CO_2 rose at times to 10, 12, and 14 parts (no

doubt as a result of the presence of furnace gases), the dry-bulb temperature never exceeded 66.5°, and the dry kata-thermometer indicated a heat loss generally over 6 millicalories, representing almost ideal conditions at the point of observation, which was at the side of the main aisle near the center of the room. It should be noted that doors and windows were open to supplement the system of fan ventilation.

TABLE III.—*Ventilation observations in shell annealing room. Feb. 25, 1919. (Station near oven 28—middle of room to one side of center aisle.)*

Time.	Heat loss, millicalories per square centimeter per second.		Psychrometer.		Per cent relative humidity.	CO_2. Parts per 10,000 of air.	Remarks.
	Kata wet.	Kata dry.	Wet.	Dry.			
p. m.							
2.10	18	6.0	45.0	59.5	27	11.0	Room atmosphere clear.
2.15	18	6.4	47.5	61.0	33	8.6	Comfort vote: Slightly cool.
2.30	18	6.4	48.0	62.0	32	7.6	Cool drafts were felt occasionally throughout run.
2.45	18	6.5	51.0	65.5	33	5.6	
3.00	21	6.3	49.0	64.0	30	4.4	Outside weather, damp, cloudy. Wet, 39; dry, 44; per cent relative humidity, 63.
3.15	18	5.6	49.5	63.5	33+	6.4	
3.30	18	5.6	52.0	66.5	34+	5.5	
3.45	18	5.7	51.5	65.5	35.5	9.4	
4.00	17	5.4	52.5	64.5	43+	12.0	
4.15	18	5.8	50.0	61.0	44	14.0	
4.30	19	6.5	49.0	60.0	43	11.8	
4.45	18	6.8	49.0	61.0	40	10.8	
5.00	18	6.3	50.0	62.5	39+	6.6	

5. DETAILED STUDY OF ATMOSPHERIC CONDITIONS IN SHELL-WASHING SHOPS WHERE HEAT AND HUMIDITY WERE CONTROLLED BY FAN VENTILATION.

Our most extensive studies along this line were conducted in two shell-washing shops. In these workrooms brass shells are washed in order to remove the oil and grease of the previous mechanical operations. Briefly described, the operation is as follows: One "service" box of shells is emptied into a cylindrical washing-tub mounted on a slightly inclined axis, and a measured quantity of soda is added. The tubs are then revolved by power, and hot water is turned on so as to wash the shells in continuously running water. Next, acid is added (sulphuric, 2-4 per cent) and the tubs are again revolved. Soap solution is added to neutralize the acid and perhaps assist in giving the shells a polish. The shells are partially dried by continuous operation of the tubs and lastly completely dried in a hot-air drier at the center of the room.

The first of these rooms studied (Shop A), which is 53 by 146 by 12 feet, is arranged with two rows of tubs along the length of the room, one row on each side. Above each row of tubs is an exhaust duct built for the removal of the warm air and steam arising from the washing operation. In addition, the room is provided with a central duct for the supply of tempered fresh air. The air for this system is

taken in from the street about 15 feet above the sidewalk level and is then passed through a series of Vento heating coils and into the shop. The exhaust fans are multivane fans, and each of them when observed by us was running at between 350 and 355 r. p. m. The supply fan is a multivane fan, running at between 190 and 195 r. p. m. The amount of air actually delivered to, and exhausted from, the room was determined by anemometer readings taken at the face of the intake duct and at the roof openings from the supply and exhaust systems, respectively. These measurements showed a plenum supply of 1,990,000 cubic feet per hour, and a total exhaust of 1,780,000 cubic feet per hour, which, with a workroom of 84,840 net cubic feet capacity (sections partitioned off being deducted), indicates 23.5 air changes per hour. The temperature of the incoming plenum air was 70° F. dry bulb and 52° F. wet bulb.

In our studies of these shops we first made observations under normal conditions, with the fans in operation, then stopped the fans to see what would happen without artificial ventilation, and finally started the fans once more for a third series of records.

TABLE IV.—*Ventilation observations, Wash Shop A. Feb. 17, 1919.*

[Sta. near Tub 27.]

Time.	Heat loss, millicalories per square centimeter per second.		Psychrometer.		Per cent relative humidity.	CO_2. Parts per 10,000 of air.	Remarks.
	Kata wet.	Kata dry.	Wet.	Dry.			
p. m.							
1.50	20	4.5	....	....	....	5.2	
1.55	21	4.5	63.0	82.0	33.0	5.7	
2	20	4.3	64.0	83.0	34.0	9.6	
2.05	18	4.1	66.2	82.2	42.0	....	
2.10	21	4.3	66.0	83.5	38.0	9.8	
2.15	22	4.7	63.1	82.5	32.0	....	
2.20	19	4.2	65.3	83.0	38.0	....	
2.25	18	4.3	63.5	82.5	33.0	9.8	Fans off.
2.30	12	2.8	70.5	81.5	58.0	16.5	
2.35	11	2.8	69.0	80.0	57.0	17.8	
2.40	9	2.8	71.0	81.0	61.5	....	
2.45	11	2.7	68.3	83.0	48.0	10.1	
2.50	9	2.3	73.0	83.0	62.0	12.9	
2.55	10	2.3	75.0	84.0	66.5	....	
3	13	2.4	76.0	88.0	58.0	11.7	Fans on.
3.05	13	2.8	68.0	88.0	35.0	4.7	
3.10	14	3.0	67.0	86.0	36.5	....	
3.15	16	3.5	63.0	85.2	27.0	5.6	
3.20	20	3.8	62.0	85.0	25.0	11.5	
3.25	21	3.8	66.5	84.0	38.5	13.4	
3.30	18	3.9	65.0	84.5	33.0	....	
3.35	18	3.9	63.0	83.3	30.0	18.0	
3.40	21	3.9	64.8	84.0	34.0	12.8	
3.45	22	3.9	65.0	83.5	36.0	....	

Our experimental run in Wash Shop A was started at 1.50 p. m. on February 17, and, with the fans in operation, readings of the kata-thermometer, wet and dry bulb thermometer, and CO_2 determinations were made at a station situated on the east side center of

the room. In addition, wet and dry bulb readings were taken at four other stations throughout the room. At 2.25 p. m.. the fans were stopped and observations continued as before. The relative humidity increased, and after a few minutes of operation on this basis the consensus of opinion of the four investigators was that the atmosphere of the room was decidedly uncomfortable. Several of the workmen in the room complained of the heat. At 3 p. m. the fans were again put in operation and observations continued until 3.45 p. m., when the experiment was closed.

The results of this test are shown in Table IV and have been plotted in Figure 3. The following facts are clearly shown:

1. That the room temperature before turning the fans off was less than 84° F.; that at the end of the "fans off" period this had increased to 88°; that with the fans again in operation the temperature dropped to 83°–84° in 35 minutes.
2. That the relative humidity increased from an average value of 35.7 per cent in the starting "fans on" period to an average value of 58.7 per cent in the "fans off" period.
3. The kata wet bulb heat loss decreased from 18 to 9 millicalories per square centimeter per second in the "fans off" period. The kata dry bulb heat loss decreased from 4.3 to 2.3 millicalories.
4. The CO_2 content of the air varied considerably during the first period of the experiment, the highest figure reached being 9.8 parts per 10,000. In the early part of the "fans off" period it reached 17.8 parts, running down to 10.1 parts at the middle of this period. At 3.35 p. m., about one-half hour after the fans were turned on, the CO_2 content again rose to 18 parts per 10,000. CO_2 is given off from the decomposition of soda ash (Na_2CO_3) during the process of washing the shells, and the determinations have, therefore, no great bearing on the efficiency of the ventilation systems, for at intervals a greater or lesser amount of CO_2 may be blown over toward the apparatus at the time of sampling.

In general, it is clearly evident that while conditions in this workroom under normal operation were by no means ideal (temperature over 80°), they would be almost unbearable without the very efficient system of ventilation which has been installed. Wet bulb temperatures of 75° and 76° and kata-thermometer heat losses below 10 millicalories for the wet and below 2.4 millicalories for the dry bulb, obtained when the fans were shut off, represent conditions which constitute in our opinion, a serious menace to health and efficiency, the combination of heat and humidity in such a shop being far more objectionable than a much higher degree of dry heat. The rise of the curve for temperature (both wet and dry bulb) and the drop for kata-thermometer heat losses during the period when the fans were shut off and their change when the fans were started again (see Fig. 3) offer eloquent testimony to the results that the system of ventilation was accomplishing.

Another wash shop studied (B) was somewhat larger (53 by 205 by 12 feet), but essentially similar in general arrangement to the first. The net cubic contents of this room were 123,324 cubic feet. Ventilation

FIG. 3.—Progressive changes in atmospheric conditions in wash shop A. Effect of interrupting fan ventilation.

and heating were secured by a plenum fan (192 r. p. m.) and two exhaust fans, of which only one (309 r. p. m.) was in operation at the time of our test. According to our anemometer measurements, the

plenum supply amounted to 1,670,000 cubic feet per hour, the exhaust to 1,080,000 cubic feet per hour, giving 13.5 air changes per hour. We started our test in this room (see Table V and Fig. 4) on the morning of February 19 at 7 a. m., just as work began, with the fans in operation as above noted. The fans were shut down at 8.06 a. m. and started again at 9.05 a. m.

TABLE V.—*Ventilation observations—Wash Shop B. Feb. 19, 1919.*

Time.	Heat loss, millicalories per square centimeter per second.		Psychrometer.		Per cent relative humidity.	CO_2. Parts per 10,000 of air.	Remarks.
	Kata wet.	Kata dry.	Wet.	Dry.			
a. m.							
6.50						6.8	
7						5.9	
7.05	18	7.8	47	57	45	8.6	
7.10			54	61	63		
7.15	18	7.8	54	63	55	9.8	
7.20	17	7.7					
7.23			50.5	64	36	10.8	
7.25	21	7.8					
7.28			49.5	63.5	33.5		
7.30	17	7.0				21.7	
7.35			51	65.5	34		
7.38	15	5.9				22.8	
7.42			52	66	36		
7.45	15	5.6				15.7	
7.49			54	67	41		
7.53	14	5.2				6.7	
7.55			55	67	45		
8	16	5.5				8.9	
8.02			55.5	69.5	40		
8.06	15	5.3					Stopped fans.
8.10			58	70	48		
8.15	16	5.2	55	68	42		
8.18		6.3	56	68	46		
8.20	17						
8.22		6.4	53	65	44		
8.25	16	5.6	57.5	67.5	54		
8.30	16	5.6	63.5	69	74	9.2	
8.35	12	5.5	66	67	95		
8.38	14	5.4	65	69.5	79		
8.43	13	5.4	65	70	77	12.2	
8.47	14	5.5	65	70	77		
8.52	13	5.1	65	71	72		
8.58	13	4.9	67	72	77	11.8	
9.03	16	5.0	65	71.5	70.5	4.3	
9.08	14	4.5	66	75	62		9.05, started fans.
9.14	14	4.5	63	77	45	7.3	
9.19	13	4.2	61	76.5	40	9.9	
9.24	14	4.5	61	78	36		
9.30	14	4.5	61.5	80	33	3.7	
9.35	14	4.5	61.5	79	35		
9.40	14	4.7	61	78	36		Two of the four heating coils cut off in plenum intake.
9.45	17	5.4	60.5	77	34	6.5	
9.50	17	5.3	59	75.5	36		
9.55	17	5.3	59.5	74.5	40	6.7	
10	17	5.3	59.5	76	36		

A critical examination of Figure 4 and Table V discloses the following facts with reference to that portion of the test which was made prior to 8.06 a. m. (at which time the fans were shut down):

1. The dry bulb temperature rose from 57° F. at 7.05 a. m. to 69.5° at 8.02 a. m. During this same interval the relative humidity varied somewhat, but on the whole tended to decrease. The dry bulb kata-thermometer heat loss (in millicalories per square centimeter

per second) fell from 7.8 to 5.3, and the wet bulb kata-thermometer loss fell from 18 to 15.

At 8.06 the fans were shut down and observations were continued as before until 9.05. The facts derived from observations made in this "fan-off" period are as follows:

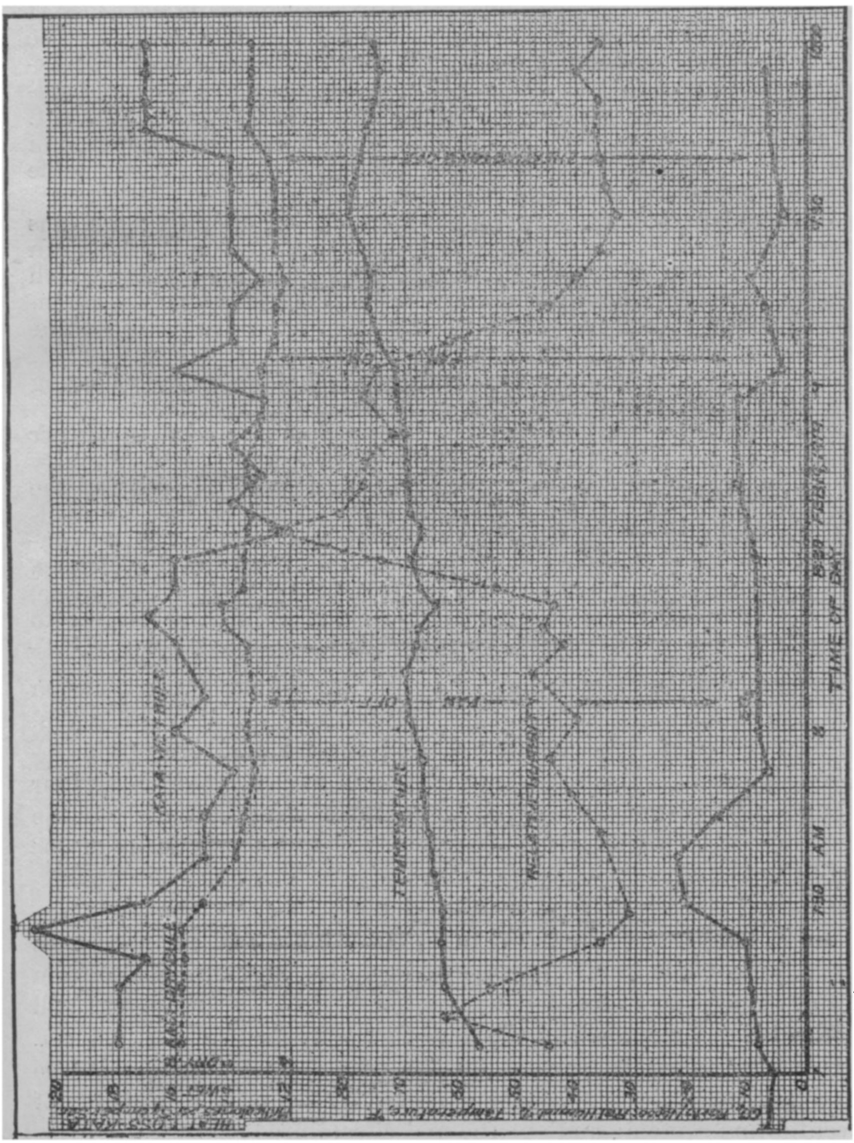

FIG. 4.—Progressive changes in atmospheric conditions in wash shop B. Effect of interrupting fan ventilation.

2. The dry bulb temperature fluctuated somewhat, the extremes being 65° and 72°, but in general continued to rise slowly. The wet bulb temperature rose rapidly from 58° at the start to 65° at the end of this period, and the relative humidity rose from 48 per cent to 70.5 per cent—at one time reaching 95 per cent. The dry bulb

kata-thermometer heat loss (in millicalories per square centimeter per second) varied slightly in this period, the extremes being 4.9 and 6.4. It will be observed, however, with the exception of the two readings taken consecutively at 8.18 and 8.22 (there may have been a local draft present at this time) that this curve is a comparatively straight line sloping slightly downward to the right, the heat loss at the beginning being about 5.3 and at the end 5.0 millicalories. The wet bulb kata-thermometer reading fluctuated considerably, the extremes being 12 and 17. It seems, however, that the general tendency of this curve was also to slope downward toward the right. In general, the room became very much more humid than it was in the first period, although conditions still remained more comfortable than in Shop A under similar conditions.

The third part of our experiment consisted in operating the fans again, thus giving us a period exactly similar to period 1. This run consisted of two parts, one from 9.05 to 9.40 a. m. (during which time four heating coils were in operation in the plenum intake chamber), and the second part from 9.40 to 10 a. m. (during which time only two of the heating coils were operating).

Considering now part one of this third period (fan on, four heating coils on), we observe the following:

3. The relative humidity dropped from 70.5 per cent to 36 per cent. The dry bulb temperature rose from 71.5° to 78°. The dry kata heat loss decreased from about 5 at start to 4.7 at end, and the wet kata heat loss remained practically constant. Judged by modern standards of ventilation, the room at this time would be considered almost as uncomfortable as it was without the use of fans. The fresh air supply had cut the relative humidity to a low value, but the temperature of the incoming air was so high as largely to nullify any advantage gained.

An examination of our data led at once to the obvious conclusion that the plenum system was supplying too much heat to the room. At 9.20 and 9.35, observations showed the temperature of the incoming plenum air to be 90° and 92°; and at 9.40, two of the four heating coils in the plenum intake chamber were shut off and the incoming air then fell (at 9.53 and 10 a. m.) to a temperature of 80° and 81°.

Observations which were continued until 10 a. m. showed a decrease in temperature from 78° to 76° (dry bulb) and an increase in dry kata heat loss from 4.7 to 5.3 millicalories, and an increase from 14 to 17 millicalories loss by the wet kata. The workroom was still overheated (as recorded by the kata-thermometer heat loss values).

This experiment brings out (a) the remarkable reduction in the relative humidity which may be expected by the proper operation of a ventilating system; and (b) the evil effects produced by the overheating of plenum air. That reasonable comfort for the worker may be secured even under severe industrial conditions is quite apparent from the observations made during the last 20 minutes.

6. HEAT HAZARD INVOLVED IN CERTAIN PROCESSES DURING THE SUMMER TIME.

It has been shown above that some of the most intense heat-producing processes in this factory were controlled with marked success during the winter season by means of fan ventilation. In summer, however, the heat hazard involved in such processes can not be eliminated except by the installation of costly systems of cooling; and it seems worth while to put on record some of the extreme conditions observed by us in this plant during the period of warm weather.

The manufacture of small arms includes a number of processes involving exposure to high temperature, such as forging, annealing, brazing, and browning. In the browning process a large amount of moisture is discharged into the air and a high temperature is necessary in order to prevent the condensation of moisture upon the gun parts in other stages of the work, so that heat and atmospheric humidity are combined. These conditions were dealt with as far as is practicable in the plant under observation by a general plenum system of room ventilation, a special plenum system for blowing the steam away from the workers and a set of low pressure exhaust fans in the wall behind. In the brazing and forge shops the operatives are exposed not only to high temperatures but to radiant heat, the evils being mitigated in the former case by exhaust hoods over the muffler and individual fans blowing air over the workers and in the latter case by screens placed before the ovens. The shell anneal shop is in summer the most intensely overheated room in the entire plant, on account of the extremely high temperature maintained in the furnaces which it contains, the elaborate system of fan ventilation which proves so successful in winter (see sec. 4 of this report) being, of course, powerless to maintain a reasonable temperature when the outside air is warm.

In studying the summer heat hazard we installed recording thermometers (of the Tycos type) in some of the hottest rooms and obtained continuous temperature records in the shell anneal shop from May 3 to July 12, 1918 (with the exception of one 25-hour period), in the forge anneal shop from June 1 to August 15, 1918 (with the exception of one 90-hour period), in the brazing shop from May 11 to June 1, and in another forge anneal shop from August 29 to September 11. The general distribution of observations is indicated in Table VI.

TABLE VI.—*Distribution of hourly shop temperatures by 5° intervals.*

	Temperatures (degrees F.).							
	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99
Shell anneal shop:								
Number hours, May 3-July 12	6	17	18	74	172	194	249	169
Per cent of total hours	0.3	1.0	1.0	4.4	10.6	11.6	14.9	10.1
Forge shop:								
Number hours, Aug. 29-Sept. 11	10	21	23	27	43	22	35	59
Per cent of total hours	3.0	6.4	7.0	8.3	13.4	6.8	10.7	18.1
Forge shop:								
Number hours, June 1-Aug. 15	....	23	75	185	292	371	309	211
Per cent of total hours	....	1.0	4.4	10.9	17.2	21.8	18.2	12.4
Brazing shop:								
Number hours, May 11-June 1	....	....	19	195	116	57	57	42
Per cent of total hours	....	....	3.8	38.7	22.2	11.6	11.6	8.3

	Temperatures (degrees F.).								
	100-104	105-109	110-114	115-119	120-124	125-129	130-134	135	Total.
Shell anneal shop:									
Number hours, May 3-July 12	198	128	159	120	119	32	14	2	1,671
Per cent of total hours	11.8	7.7	9.5	7.2	7.1	1.9	0.8	0.1	100
Forge shop:									
Number hours, Aug. 29-Sept. 11	35	11	15	10	12	2	1	....	326
Per cent of total hours	10.7	3.4	4.6	3.0	3.7	.6	.3	....	100
Forge shop:									
Number hours, June 1-Aug. 15	124	67	40	7	3	....	....	....	1,707
Per cent of total hours	7.3	3.9	2.3	.4	.2	....	....	....	100
Brazing shop:									
Number hours, May 11-June 1	12	4	3	....	....	....	....	....	505
Per cent of total hours	2.4	.8	.6	....	....	....	....	....	100

Figure 5 shows the hourly variations of atmospheric temperature in the shell anneal shop and in a forge shop on a typical June day in comparison with the corresponding outdoor temperature. It will be noted that at 6 p. m. the forge shop reached a temperature of 110° F. and the shell anneal shop a temperature of 130° F. while the air outside was at 75°. From 1 p. m. to 9 p. m. the temperature of the shell anneal shop at this point never fell below 120° F. Our recording thermometers were in all cases placed somewhat farther from the special heat sources than the position occupied by the workers, so that the results may be taken as fairly representative.

Figures 6 and 7 indicate the temperature conditions observed at 4 p. m. (near the highest temperature point reached in the diurnal cycle) for the entire period of our study in a brazing shop and a forge shop (Fig. 6) and in the shell anneal shop (Fig. 7). The temperature of the brazing shop varied at this hour between 80° and 100° and was generally about 20° above the outdoor temperature. The forge shop was even hotter, between 80° and 120°, and the shell anneal shop was usually between 100° and 120° and averaged about 40° higher than the outside air.

The vigorous air movement and the dryness of the atmosphere make conditions in this workroom less objectionable than they would be on the basis of temperature alone; but in any event, the exposure to temperatures of 120° and over must exert a serious strain upon the adaptive powers of the human organism.

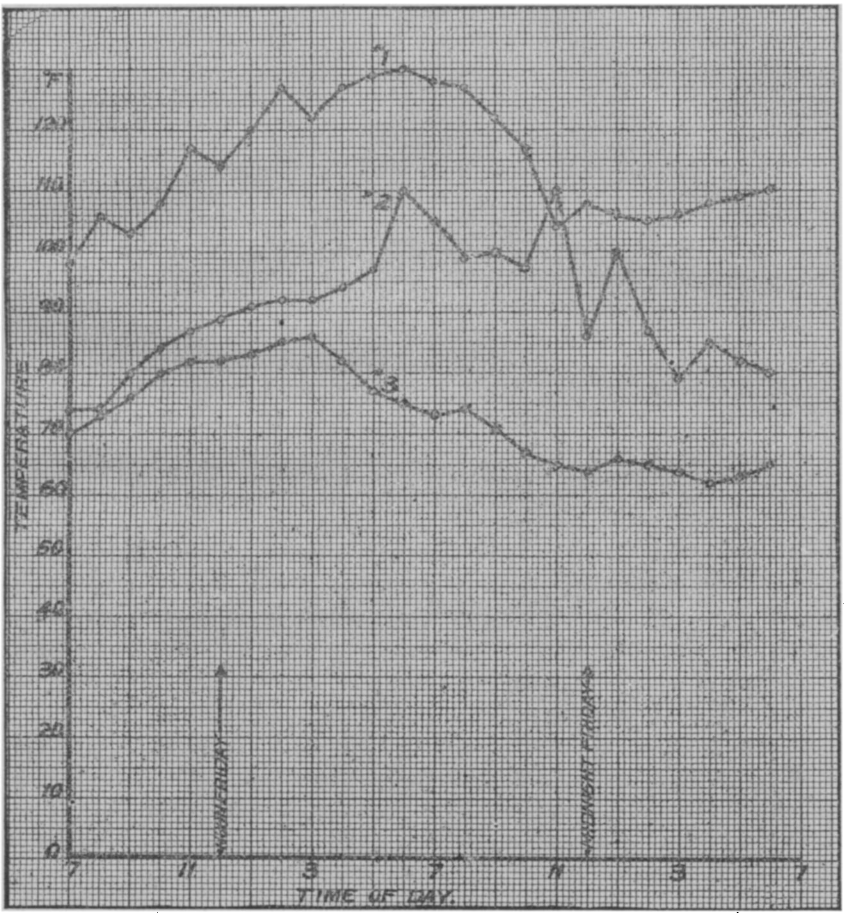

FIG. 5.—Hourly variations in temperature in shell anneal shop (curve No. 1) and forge shop (curve No. 2) compared with outside temperature (curve No. 3) on a typical June day.

7. CONCLUSIONS.

The data here reported suggest the following general conclusions, which are supported by the general experience of the writers in the study of atmospheric conditions in many other plants.

A. The commonest evil in the field of air-conditioning is the slight but highly objectionable overheating which obtains in the ordinary window-ventilated factory workrooms where there is no marked overcrowding and no special process tending to overheat or vitiate

the air. This evil can generally be controlled by routine observation of thermometers, the application of common sense to the regulation of artificial heat sources, and the use of windows before and during the shift.

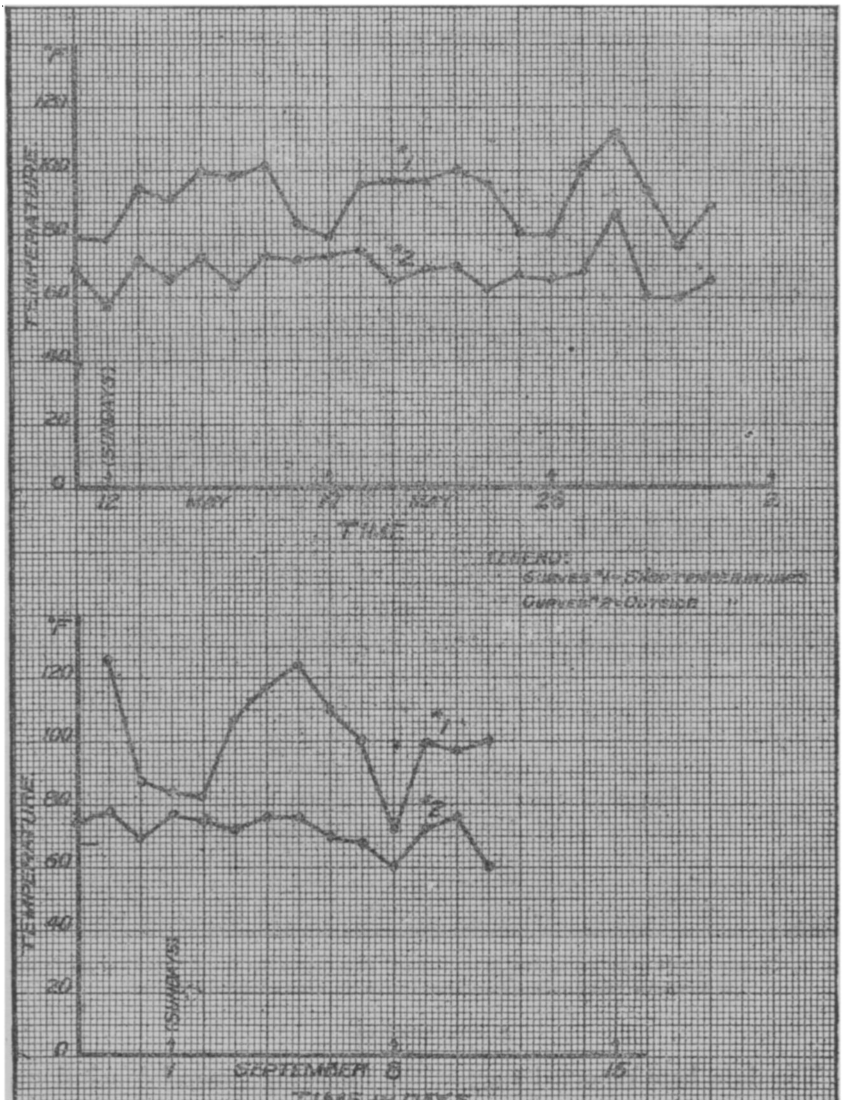

FIG. 6.—Daily variations in 4 p. m. temperature in a brazing shop (above) and in a forge shop (below) compared with outdoor temperature at the same hour.

B. Heat hazards of a high degree of intensity can be adequately controlled during cool weather by properly designed and operated systems of fan ventilation.

C. In summer time, while the hazard incident to processes involving the production of excessive heat can and should be mitigated to some extent by a system of ventilation which produces vigorous air movement, it can not be fully controlled except by special systems

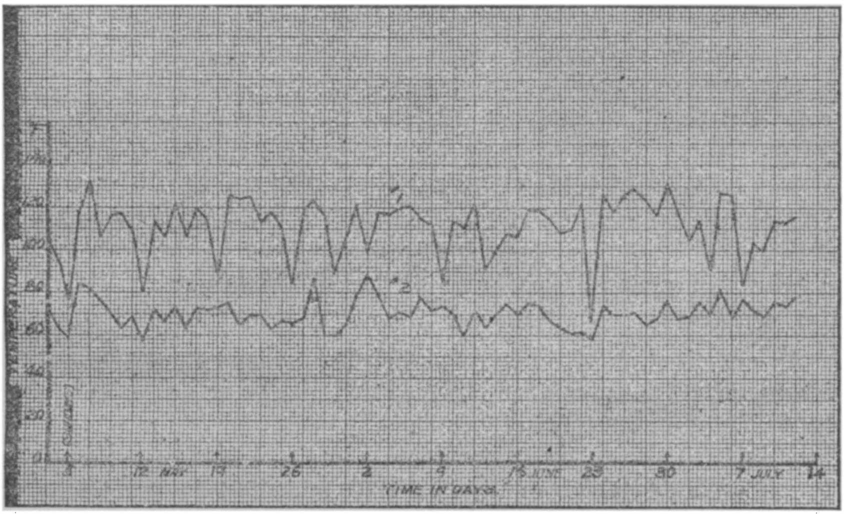

FIG. 7.—Daily variations in 4 p. m. temperature in shell anneal shop (curve No. 1) compared with outdoor temperature (curve No. 2) at the same hour.

of air cooling which would involve a prohibitive expense and must, in general, be accepted as an inevitable incident of certain industrial employments. Where this is the case, the effects of the high temperature should be minimized by short spells of work alternating with rest periods.

THE UNITED STATES LIFE TABLES.

The Department of Commerce, through the Bureau of the Census, announces that the second official publication on life tables derived from births, deaths, and populations in this country, is soon to be issued. These tables show conditions as they existed in 1890, 1901, and in 1910, thus making it possible to study the changes which have taken place in mortality during two decades.

MORTALITY VARIES WITH THE CLASS.

It is shown that mortality at practically all ages is higher among men than among women. In particular it appears that the most favorable mortality in this country is found among women living in the rural districts. The rural classes, regardless of sex, enjoy a much lower mortality for nearly the entire range of life than those living in the cities. While the expectation of life among both men and